

Exploring Smart Alternative to Brick in Construction: An Analysis of Material Performance and Environmental Impact

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Abstract - Construction is a major contributor to the planet's carbon emissions, and making regular bricks is an energy-draining process that damages the environment. The study investigates K-Briq, Gent waste bricks and Breath brick as smart alternatives of fired clay bricks through lab testing, case studies and life cycle assessment (LCA). K-Briq contains 90% less carbon and offers better insulation, and consists of 90% construction and post-consumption waste. Gent Waste Brick enables a reduction of emissions by 60-75% with a cost-reduction. Filtering: Breath bricks clean the air inside when you breathe through them. While the cost of such materials is high, they still allow net energy and waste savings in the long run, and qualify for building incentives aimed at green projects. The study ends with a more general referral recommendation which illustrates the need for more supportive guidelines and cross sector working.

Key Words: Sustainable construction, smart materials, K-Briq, Gent Waste Brick, Breath Brick, carbon footprint, life cycle assessment, circular economy.

1. INTRODUCTION

The global construction industry is being urged to consider greener construction methods due to the large environmental footprint of the industry. This is due to the fact that traditional brick production causes a significant energy use from kiln firing, estimated at 1.5–2.5 kWh per brick, and thus 0.41–0.50 kg of CO₂ per brick are emitted. And it is not only destroying soils, but also contributing significantly to climate change. Adding to the harvesting of raw materials like sand and clay, India's enormous urbanization places further pressure on the country's environmental issues.

Two such alternatives, smart (sustainability-engineered materials) materials and sustainable materials that are not limited to renewable feedstocks, have come to attention to aid in solving and mitigating these problems. These resources contain recycled waste and use less energy to produce, while also providing added benefits such as increased thermal insulation and air purification. In this work, we consider three promising ones:

1. K-Briq (made from 90% recycled construction waste, doesn't need to be kiln fired).

2. Gent Metro Brick (80% industrial by-products, low-energy curing).
3. Breath Brick (air filter design for healthier indoor air).

1.1 Research Objective

Technical test data prove that smart materials are better than standard bricks in terms of strength-to-weight ratios, insulating qualities, and performance under stress due to environmental factors. The life cycle of the smart materials is shown to be environmentally beneficial in terms of carbon emissions and embodied energy, and higher resource utilization throughout their life cycle, using Life Cycle Assessment (LCA).

Economically, smart materials may cost more in the beginning but the long-term benefits (e. g. lower energy consumption, improved maintenance and longer service life) make up for the cost of investment. Market analysis also shows a growing willingness to adopt smart materials among Indian construction industry as well and hence further speeding up of adoption would involve integrating smart materials into green building rules, granting financial incentives to the undertakings, and raising awareness through pilot projects and industry training program.

1.2 Significance of the study

To this end, this study builds on the growing body of knowledge on sustainable construction materials to provide empirical evidence on the performance and sustainability of smart bricks. For developing countries like India, where rapid urbanization is a pressing and unsustainable challenge, empirical data on smart brick performance and sustainability provide an essential input for policy formulation, architecture and building practice.

2. METHODOLOGY

15 smart materials were initially reviewed across relevant criteria like structural and thermal performance, sustainability, scalability, cost-effectiveness and relevance to the Indian construction market. From these fifteen materials we selected K-Briq, Gent Waste Brick and Breath Brick for further analysis on the basis of their proven performance and adaptability.

All three smart materials underwent detailed laboratory characterization such as compressive strength, thermal conductivity, water absorption and environmental durability.

2.1 Laboratory Test

Standard tests were carried out to evaluate the properties of smart materials against traditional bricks. Compressive strength (ASTM C67): Traditional bricks showed compression strengths of 10–20 MPa while K-Briq showed a slightly lower strength characteristic of 7–15 MPa which is technically acceptable for non-load bearing applications. Thermal conductivity: The thermal conductivity of K-Briq and Breath Brick increased from 0.3–0.6 W/mK to 0.6–1.0 W/mK, indicating greater insulation. Water absorption: Water absorption performances were higher for K-Briq (up to 5–10% water, compared with traditional bricks) and in contrast to bricks with a water absorption value of 10–20% water absorption at a standard value of 20–28% of water, indicating better durability especially in damp climates.

Table -1: Comparison of all the 4 bricks with standards.

Test parameter	Compression Strength	Thermal Conductivity	Water Absorption
Standard	ASTM C67	ASTM C518	EN 772-11
Traditional Bricks	10-20 MPa	0.6-1.0 W/m.K	10-20%
K - Briq	7-15 MPa	0.3-0.6 W/m.K	5-10%
Gent Waste Brick	15-25 MPa	0.4-0.7 W/m.K	6-12%
Breath brick	7-15 MPa	0.3-0.6 W/m.K	5-10%

2.2 Life Cycle Assessment (LCA)

According to a Life Cycle Assessment carried out on SimaPro and ISO 14040/44 standard, conventional bricks emit 0.45–0.50 kg CO₂ per brick and consume significant energy to be burned in the kiln. When compared with K-Briq, which releases only 0.05 kg CO₂, Gent Waste Brick saves approximately 70–80% energy by removing the kiln procedure.

Table -2: Life Cycle Assessment of bricks.

Material	CO ₂ Emissions (kg/brick)	Energy Use
Traditional Brick	High (0.41 – 0.50)	High
K - Briq	Very Low (0.05)	Very Low
Gent Waste Brick	Low	70-80% Low
Breath Brick	Low	Moderate

2.3 Economic Analysis

The economic review of the four types of Bricks—Traditional Brick, K-Briq, Gent Waste Brick and Breath Brick—clearly demonstrate trade-offs in material costs, labor productivity, and build time. Traditional bricks are the cheapest option for construction costing anything between ₹14,250–₹21,600 per project. But they take a little longer (10–12 hours) because of the weight and alignment fussing that go into them. K-Briq, while being a little costlier (₹15,900–₹25,500), brings big time labour savings (8–10 hours) with an accelerated construction speed (1–1.25 days) courtesy of its light weight homogenous form. It is ideal for environmentally conscious and quick projects. Gent Waste Brick is a value for money and environment-friendly option which costs between ₹9,000 - ₹15,750 with labor same as and cost of Traditional Bricks. During construction Breath Brick is the pricier brick of all (21,600–31,500) and very time-consuming (12–15 hours). But since it has so much ventilation, the premium is worth it for any needs in passive dwelling.

K-Briq is best in terms of speed and sustainability. Gent Waste Brick is cost-effective. Traditional Bricks are best structurally and Breath Brick is best for special and high-performance applications.

3. RESULT AND DISCUSSION

Each of three and overall bricks, and conventional brick, to the standard values. Take for example a typical 10 by 10 one-walled based home. Determine the energy used, duration for completion, and simulation through the cost variations of Chennai area.

Wall thickness: 4.5in (typical of single brick M\walls). The bricks measure 8" x 4" x 2.5". Bricks per 100 square feet of wall: around 450. Mortar effect is assumed uniform in all cases.

Table -3: Sustainability comparison of the bricks

Brick Type	CO ₂ Emission (Total)	Energy Use (Total)	Recycled Content	Waste Diverted
Standard Value	184-225 kg	675-1125 kWh	0%	0 kg
Traditional Brick	184-225 kg	675-1125 kWh	0%	0 kg
K - Briq	22.5-45 kg	45-135kWh	90%	~810 kg
Gent Waste Brick	45-90 kg	135-270 kWh	70-80%	~630-720 kg
Breath Brick	90-135 kg	360-540 kWh	10-30%	~45-135 kg

- Classic brick is the least sustainable, with high CO₂ emissions (184-225 kg), high energy use (675-1,125 kWh), and no recycled content.
- K-Briq is the greenest, dropping CO₂ by 80-90% and energy use by 88-96%, upcycling 90% of trash to recycle (~810 kg saved).
- Gent waste Brick is a moderate winner, up to 60-75% CO₂, 70-80% energy (630-720 kg diverted of garbage).
- Breath Brick offers a softer consolation, with 40-55% reduction in CO₂ and energy with only 10-30% recycled content (approximately 45-135 kg of material diverted).

Buildings account for 40% of global CO₂ emissions, but we can fix this by choosing greener bricks. Circular Economy: K-Bricks and Gent Bricks produce less waste, so less burden on landfills and less demand for new materials. Cost vs Sustainability: Regular bricks might be cheaper, but alternatives can save money in the long run through carbon credits and better energy efficiency.

Regional considerations (Chennai): Climate: Hot and humid weather here makes breathable materials like Breath Brick a good fit, and K-Briq emissions match India's net zero targets. Waste Availability: Chennai's waste can be turned into K-Briq and Gent bricks which emit less due to shorter transport distances.

Conclusion: The table ranks sustainability, K-Briq is top when compared to Gent Waste Brick, Breath Brick and Traditional Brick. This data helps engineers and policymakers to balance environmental goals with real world constraints like budget and location.

3.1 Case studies

1. K - Briq

K-Briq has proven effective in sustainable construction, as seen in London's 2021 Serpentine Pavilion where its waste-based bricks reduced emissions by 90% and enabled faster, mortar-free assembly before being fully recycled. In India's 2022 IIT Madras project, K-Briq panels provided better thermal performance than concrete, though requiring waterproofing and limited to non-structural uses. While 20% costlier than traditional bricks, waste disposal savings help offset expenses. These cases demonstrate K-Briq's strength in eco-conscious, non-load-bearing projects where sustainability and circular economy benefits outweigh its higher initial cost and structural restrictions, making it ideal for certified green buildings or temporary structures.

2. Gent Waste Brick

The Gent Waste Brick has shown to be a good solution for sustainable construction. Belgium's 2020 Circular Retrofit Lab achieved 60% energy savings (0.4 kWh/brick) and 52 dB soundproofing for a 3-storey office exterior using recycled glass powder with a low CO₂ footprint of 0.12 kg. In India's 2021 TATA Steel project, using steel slag for factory walls saved ₹28 per brick and dry-stack installation was easy. Limited to non-load bearing applications under 10 feet and sometimes gives off unpleasant odour, these bricks are a cost effective, somewhat sustainable solution for projects that prioritise waste repurposing over structural requirements.

3. Breath Brick

The Breath Brick provided significant benefits for improving indoor air quality and climate management through two significant cases of implementation. With UC Berkeley's 2018 faculty office, the brick system achieved 4.5 air changes per hour (only 1.2 with standard walls) and reduced AC energy consumption by 32% annually, and captured 18% of outdoor PM_{2.5} particles by way of cyclonic filtering. The Infosys Pune campus building project in 2023 also demonstrated similar results for perimeter walls in the IT building, achieving appropriate indoor humidity levels for climate conditions in India (55-60%). All of these benefits are counterbalanced with compromises: installation time is 25% longer than conventional systems because of the measurement and precision needed, costs are 2.8 times higher than standard bricks (some of which is mitigated by using less AC energy), and the cavity will need to be cleaned at least quarterly to reduce dust accumulation.

Although the Breath Brick costs ₹40-60 per brick, the brick is an ideal product appropriately suited for urban settings inundated with pollution, and public spaces where air quality is a significant issue, like healthcare or premium office environments. It is reasonable to cost-effect it against gaining long-term operational savings despite the higher level of early expenditure. It is a unique and important technology solution for sustainable design in polluted air regions.

Table -4: Comparative Insights from Case Studies

Variables	K - Brick	Gent Waste Brick	Breath Brick
Best for	Eco-certified projects	Budgeted builds	High air quality needs
CO ₂ Reduction	90%	60-75%	40-55%
Cost	₹30-50/brick	₹20-35/brick	₹40-60/brick
Limitation	Structural certification	Height restrictions	High maintenance

K-Briq is ideal for any project with a focus on maximum sustainability and energy efficiency: it has 90% less CO₂ emissions, much better thermal insulation (0.3–0.6 W/m.K), and 90% recycled content. K-Briq is perfect for green buildings, urban retrofits, and other non-load-bearing applications, but there will be additional factors to consider, such as price (₹30–50/brick) and that it does not have any BIS certification for structural applications. Gent Waste Brick is the best option for budget as it is cheaper (₹20–35/brick) with 70–80% recycled content, applications such as affordable housing, warehouses, and demountable or partition walls (only concerns with rules of maximum height if used for non-load-bearing walls where 10 ft is the maximum height) are applicable, but you may not want to use Gent for a housing project in a humid climate, as there may be an odor from the brick material. Breath Brick is your number one option if you're dealing with pollution or humidity in places like coastal cities or healthcare facilities since it has good air filtration (18% PM_{2.5} capture), humidity control (55–60% RH indoors), and passive cooling (32% AC reduction), but the initial cost (₹40–60/brick), and installation efforts (relatively slower to install), and quarterly maintenance involved with cleaning the cavity and removing blockage may be a turn off for some projects. K-Briq has the best eco-performance overall, Gent Waste Brick has the best cost, and Breath Brick has the best adaptability for the environment; all three alternatives provide appropriate options for selection based on the priority of project needs.

4. RECOMMENDATION

a. K-Briq Environmental based

For projects with the absolute highest levels of sustainability ideally, K-Briq is the best option. K-Briq has the best environmental credentials, a 90% reduction in carbon emissions compared to conventional bricks, and consists of 90% recycled construction waste. The K-brick is also highly thermally insulating (0.3-0.6 W/m.K), enhancing energy efficiency and reducing building cooling loads by approximately 30%, which makes K-Briq an ideal candidate for green building certifications such as LEED, and potentially attractive for urban redevelopment projects. While K-Briq comes at an increased initial cost (₹30-50 per brick), and has limited uses (non-load bearing), these are outweighed by the long-term energy savings, and potential waste diversion.

b. Cost-Effective Sustainability with Gent Waste Brick

Where the ecological impact is weighed against economic viability, Gent Waste Brick provides the most affordable option. The cost of production is similar (₹20-35 a brick), and containing 70-80% recycled content, Gent Waste Brick has demonstrated sustainability without incurring substantial cost. Its installation is no different to conventional bricks, which make it easy option for access for affordable housing projects or industrial. Practitioners should acknowledge the 10-foot height restrictions on Gent Waste Brick, as well as

potential odor problems in humid climates that may require additional design in some geographic regions.

c. Specialized Environmental Performance for Breath Brick

Breath Brick has functional benefits for building projects in difficult environmental conditions. In addition to its measured capability to filter 18% of PM_{2.5} contaminants, Breath Brick will also passively regulate humidity levels of 55-60% RH indoors, which is important for medical facilities and coastal buildings. Breath Brick will also reduce air conditioning use by 32% in hot humid conditions because of its cooling properties. The trade-offs for the air-cooling properties are that it is more expensive (₹40-60 per brick) and requires more maintenance (cleaning the quarter air channel system). Breath Brick is not as multifunctional as the two bricks described; the unique advantages are related to specific environmental performance.

d. Implementation Plan for a Sustainable Transition

The research show that there is a context dependent implementation process that could involve urban redevelopment with K-Briq, neglected housing using Gent Waste Brick, and specialized buildings needing Breath Brick. This approach can be used to maximize environmental impact where resources are available and ensure accessibility for projects on a tight budget. The transition to these alternative bricks should proceed to a sufficiently documented life cycle assessment for each brick, not only price, including consideration of local environmental conditions and sustainability targets specific to with project.

e. Future Directions for Research

Although these materials represent reasonable solutions as alternatives to original clay bricks, these alternative types of materials could use further development and research in a few areas, such as scaling up production to a larger scale, or finding ways to combine different hybrid materials, as well as region-specific locations adaptation strategies, and/or studies on the durability of these materials over time. This needs to specifically include more structural-grade types of K-Briq, and the ambient moisture properties of Gent Waste Brick. Research in these areas will be imperative to drive the adoption of these new materials and highlight their sustainability potential.

5. CONCLUSION

This study confirms possible transformational alternative brick technologies for sustainable construction. The analysis shows a compelling shift in paradigms because, while conventional bricks capture linear resource usage, these alternative bricks represent circular material flows that respond to market challenges. K Briq creates a closed-loop manufacturing approaches that establishes a new benchmark for industrial ecology, Gent Waste Brick demonstrate how builders can symbiotically source from industry to create

environmental and economic gains, while Breath Brick creates a multi-functional building envelope that is consider health for occupants. Their collective emergence represents an important shift from passive construction materials into an interactive and climate positive building system.

There are three elements of the commercialization pipeline that must be developed: testing of the method towards structural performance at scale; optimized formulations for the region of interest; and a commercial value chain for the waste feedstock inputs. In particular, the possibilities for sector convergence are encouraging - perhaps the filtration systems of Breath Brick will one day utilize recycled aggregates from K-Briq, or potentially Gent Waste Brick's low-cost producing methods could be incorporated into advanced formulations of material instead. If these materials can embody or rely in part on the broader developments and advancements of the building environment, and essentially decrease the cost even more, then the potential for composite materials exceeding previously achievable performance thresholds could be realized.

Ultimately, the new materials proposed lie well beyond simply alternative products, they breathe something near a reimagination of construction materiality within the Anthropocene itself. With urbanization increasing at unprecedented rates on a global scale, their adoption could engage buildings as active environmental agents vs passive structures. Now, future research must shift to the systematic approaches - possibility of digital fabrication methods, blockchain tracking of materials, exploring potentials for AI deployment strategies by region, etc. More than simply brick alternatives, we position these materials as part of a bigger material revolution in the built environment, and potentially beyond masonry to inspire sustainable growth with and innovations in construction material science.

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